

# Preliminary Analysis of fourth Cavity Production (Zanon Cavities)

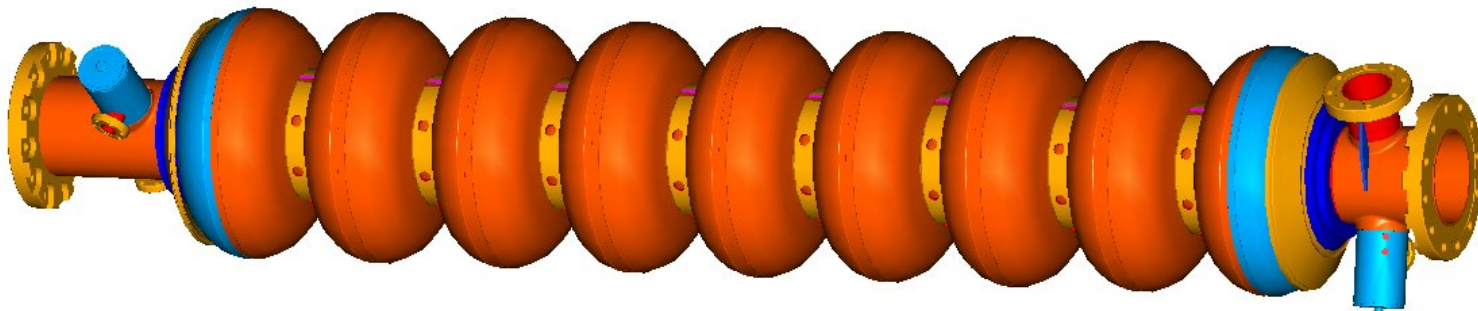
Detlef Reschke

August 2006

- Introduction
- Data analysis
- Results + Quench locations
- Vertical vs. Chechia test results
- Summary + conclusion

# Introduction

- Fourth cavity production series:
    - 30 nine-cells fabricated by Zanon company (incl. 3 prototypes with irregularities during fabrication)
    - 15 cavities of Teledyne Wah Chang Nb; 14 cavities of Tokio Denkai Nb; 1 mixed cavity
    - delivery from mid 2004 to end of 2005
  - “Standard” cavity preparation:
    - first EP of 150 $\mu$ m, outside etching, 800C firing, final EP of (40 - 50)  $\mu$ m, test, 120C bake, test
- => but many changes + exceptions !!!



# Introduction II

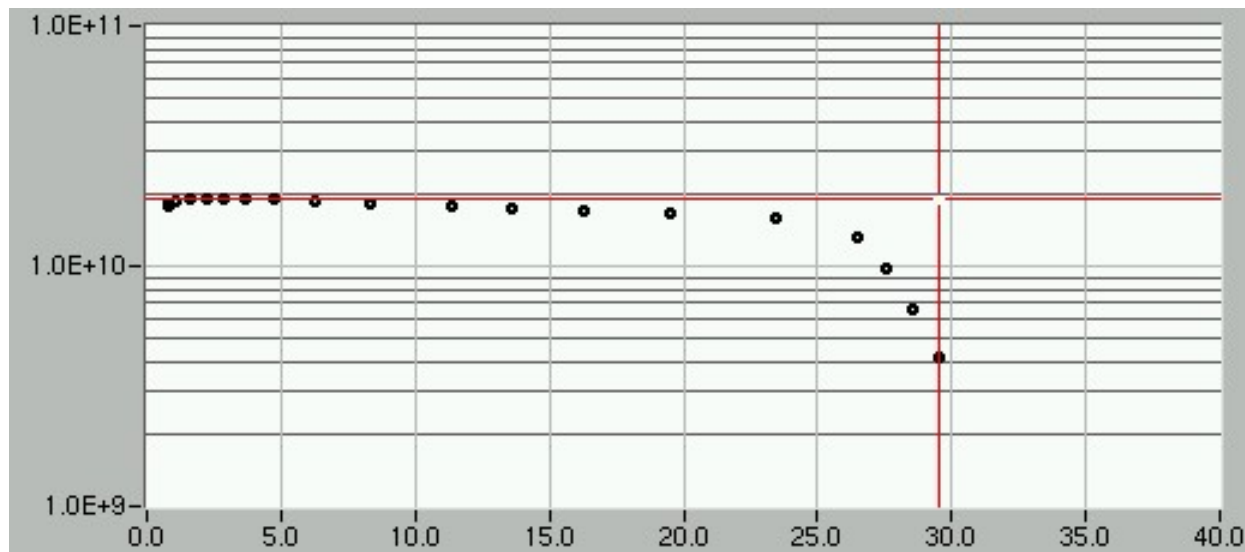
- **Cavity Processing:**
  - Z82 – Z84 (prototype cavities) got 1350C titanisation
  - 8 cavities are/will be etched (10  $\mu\text{m}$ ) as final treatment
  - 120C bake is skipped due to lack of time (=> module completion)
- **Cavity Testing:**
  - 21 cavities vertically tested
  - 7 cavities Chechia tested; 2 under preparation
- **Remark:**
  - Z84 not included due to multiple Q-disease !!
  - Z82 + Z83 after 1350C not included

# Data analysis

- Comparison of maximum and **usable** gradient after various preparations  
=> bad statistics due to many different ways of preparation
- **Usable gradient** in vertical test:  
Lowest value of gradient for either
  - quench
  - x-rays exceed  $10^{-2}$  mGy/min
  - or rf losses exceed 100 W in cw operation (**comparable to app. 1 W pulsed**)  
=> limitation of cryogenics !!
- Analysis of
  - final EP- vs. BCP-treatment
  - comparison before and after 120C bake
- **Not** strictly following “first/last/best test” like in data base  
=> Choice of “reasonable” test (see add. transparencies)  
(e.g. 14 of 20 cavities first test used before bake)

# Expectation: 800C, **EP**, before bake

- Preparation: **final EP** after 800C firing + 150 $\mu$ m EP **before** 120C bake
- Expectation for a “good” (typical) cavity:
  - $E_{acc,max}$  between 25 MV/m and >30 MV/m, Q-slope without field emission, limited by available power, no up to moderate field emission
  - **Usable gradient** between 25 MV/m and 30 MV/m limited by rf/cryo losses
- Typically cavities **not used for accelerator without bake, but ...**
- Example of Z87:

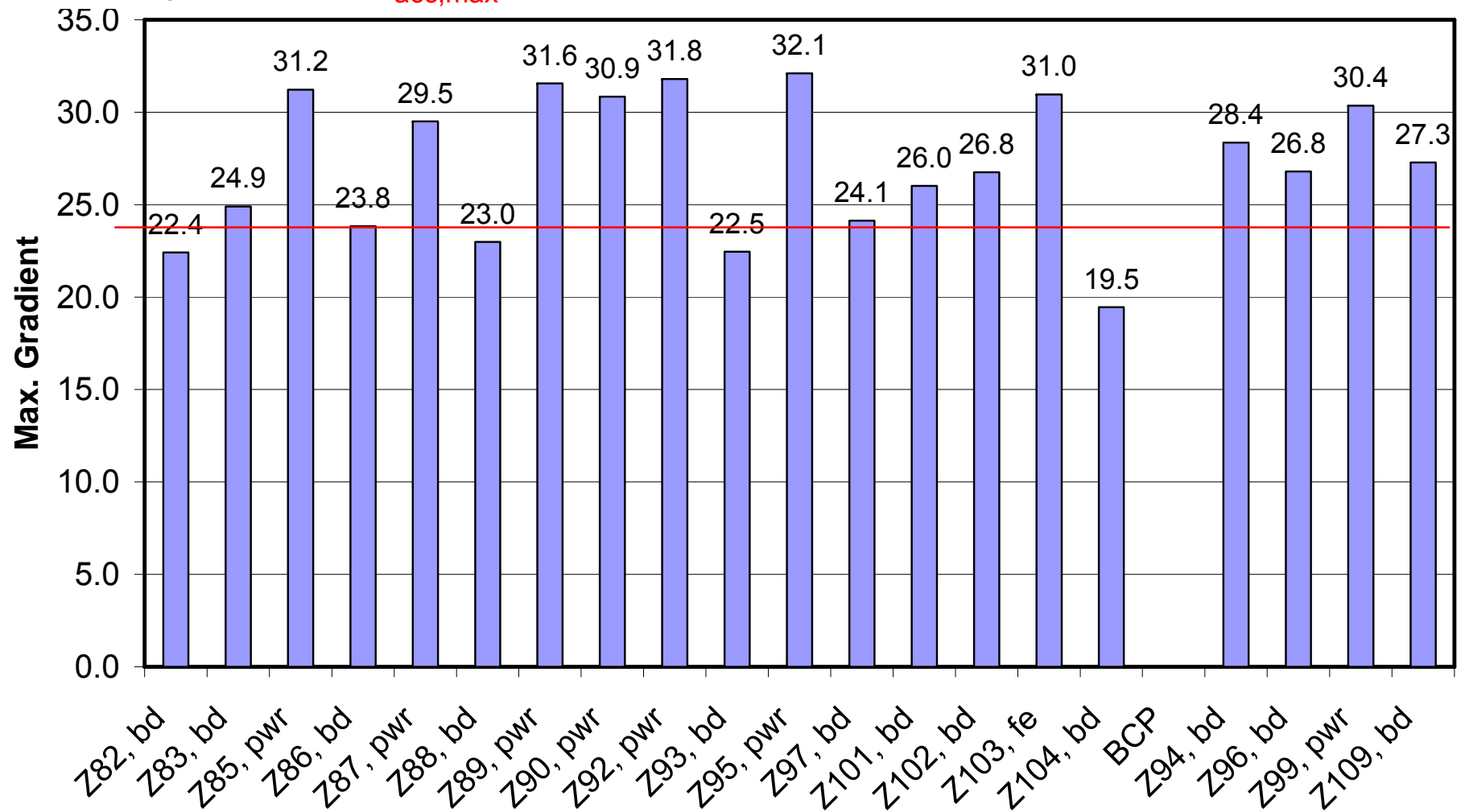


# Results: 800C, EP, before bake

- Analysis of 16 cavities after **final EP**, before 120C bake :
- **Maximum gradient**  $E_{\text{acc,max}}$ 
  - 9 cavities limited by quench (bd)
  - 6 cavities limited by power
  - 1 cavity by FE (extremely high x-ray level=
- 7 of 9 cavities limited by quench **below 25 MV/m !!**
- Some quenches maybe field emission induced e.g. Z82, test1 !!!
- **Usable gradient:**
  - **for 8 cavities field emission dominates !!**
  - 4 cavities are quench limited =>  $E_{\text{acc,max}} \approx$  **usable gradient**
  - 4 cavities exceed tolerable cryo losses (partially close to quench)

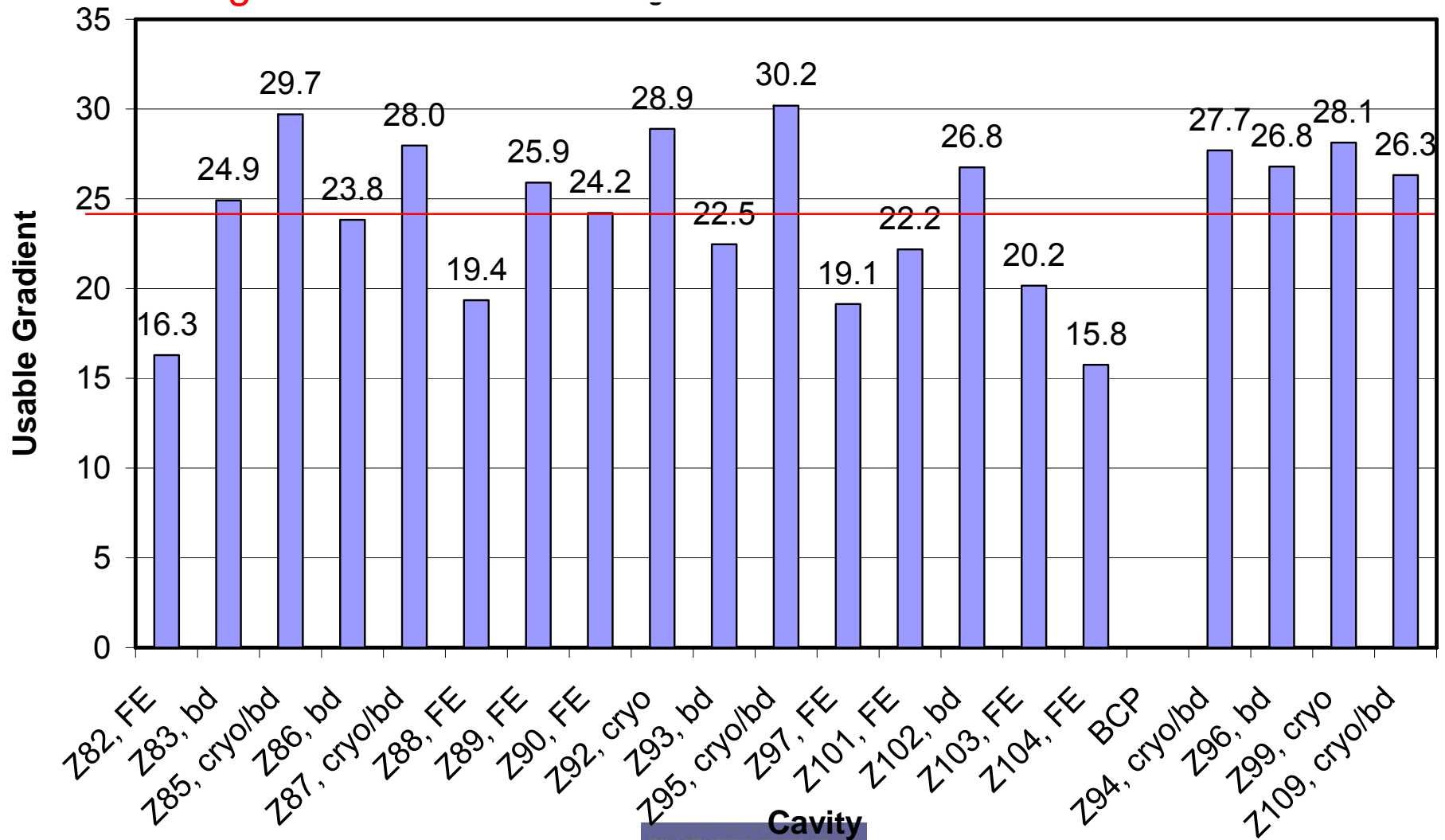
# $E_{acc,max}$ before 120C bake

- Comparison of  $E_{acc,max}$  after final EP and BCP-treatment before 120C bake:



# Usable gradient before 120C bake

- Usable gradient after final EP and BCP-treatment before 120C bake:



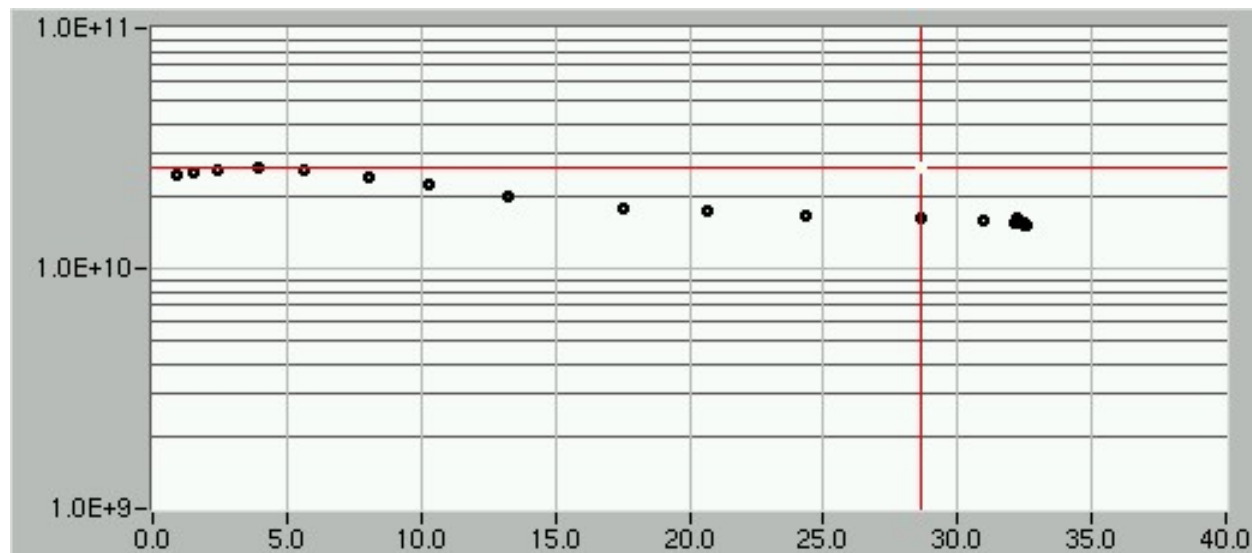


# Results: 800C, **BCP**, before bake

- Preparation: **final BCP of 10 $\mu$ m** after 800C + 150 $\mu$ m EP **before** 120C bake
- Expectation for a “good” (typical) cavity:
  - only few data available, but probably similar to “pure” EP ( $E_{\text{acc,max}}$  between 25 MV/m and >30 MV/m, Q-slope without field emission, limited by available power, no up to moderate field emission)
  - **Usable gradient** also similar (between 25 MV/m - 30 MV/m limited by rf/cryo losses)
- Intended to treat and test 8 cavities => 4 cavities done
- **Maximum gradient**  $E_{\text{acc,max}}$ 
  - 3 cavities limited by quench (bd)
  - 1 cavity limited by power
- **Usable gradient:**
  - 1 cavity quench limited =>  $E_{\text{acc,max}} \approx$  **usable gradient**
  - 3 cavities exceed tolerable cryo losses (partially close to quench)

# Expectation: 800C, **EP**, after bake

- Preparation: **final EP** after 800C firing + 150 $\mu$ m EP **after** 120C bake
- To achieve full Q(E)-performance of EP-cavities 120C-bake is required!!
- Expectation for a “good” (typical) cavity:
  - $E_{\text{acc,max}} > 30$  MV/m, no or nearly no Q-slope, limited by quench (bd), no up to moderate field emission
  - **Usable gradient**  $> 30$  MV/m (?) limited by rf/cryo losses
- Example of Z87:



# Results: 800C, EP, after bake

- Analysis of 7 cavities after final EP, after 120C bake :
  - Maximum gradient  $E_{\text{acc,max}}$ 
    - 6 cavities limited by quench (bd) between 24,5 MV/m and 33 MV/m
    - 1 cavities limited by rf-problems

=> 3 cavities limited by quench just below 25 MV/m !!
  - No cavity exceeds x-rays of  $10^{-2}$  mGy/min !!
- => Often no improvement after 120C bake due to quench limitation!!

## Usable gradient:

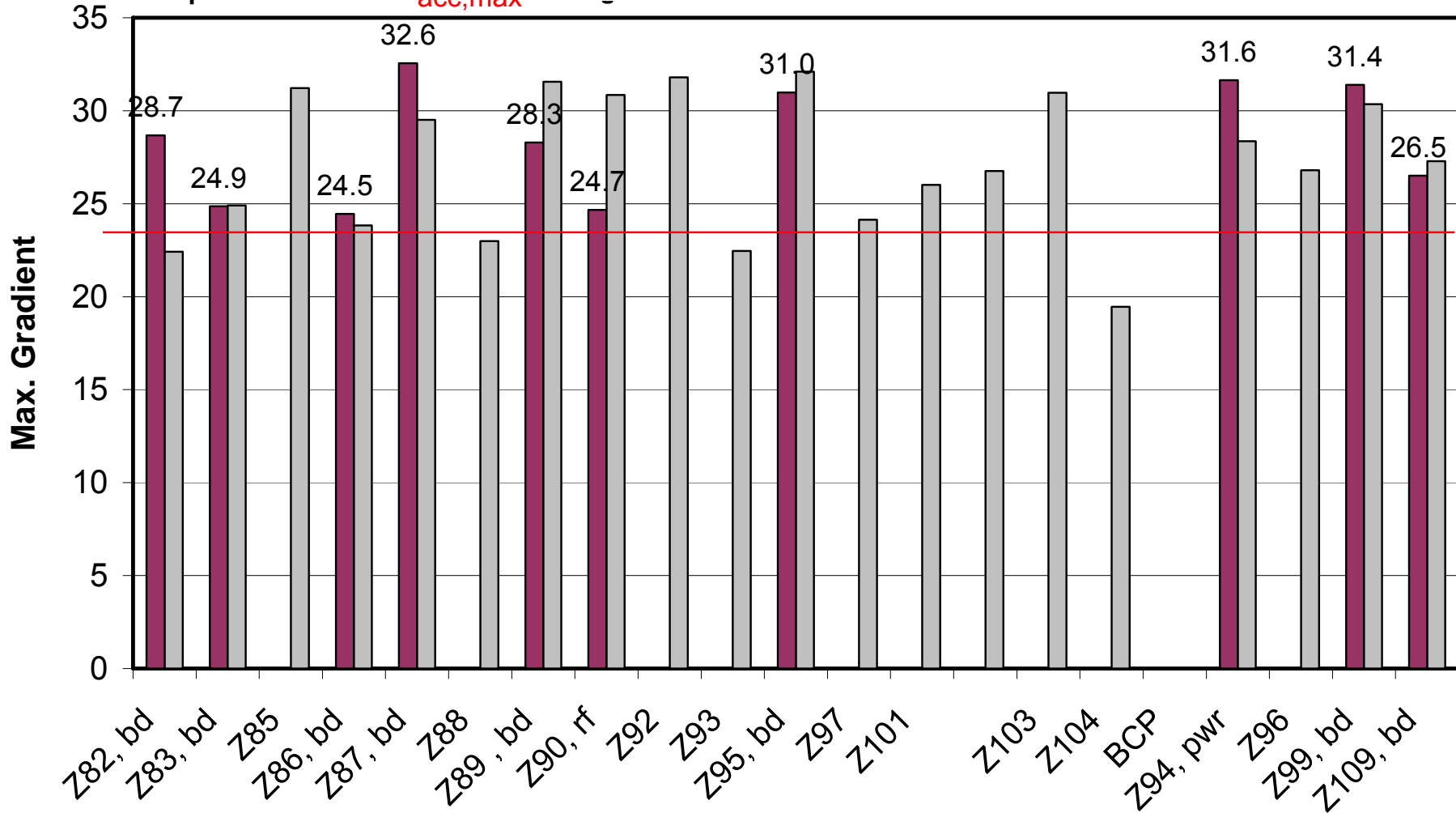
- 6 cavities are quench limited =>  $E_{\text{acc,max}} \approx$  usable gradient
- 1 cavity rf limited =>  $E_{\text{acc,max}} \approx$  usable gradient

# Results: 800C, **BCP**, after bake

- Preparation: **final BCP of 10 $\mu$ m** after 800C + 150 $\mu$ m EP **after** 120C bake
- Expectation for a “good” (typical) cavity:
  - only few data available, but probably similar to “pure” EP ( $E_{\text{acc,max}} > 30$  MV/m, (nearly) no Q-slope, limited by quench, no up to moderate field emission)
  - **Usable gradient** also similar ( $> 30$  MV/m (?) limited by rf/cryo losses)
- Intended to treat and test 8 cavities => only **one cavity tested** after bake !!
- **Maximum gradient**  $E_{\text{acc,max}}$ 
  - 1 cavity limited by quench
- **Usable gradient:**
  - 1 cavity exceeds tolerable cryo losses (2 MV/m below quench)

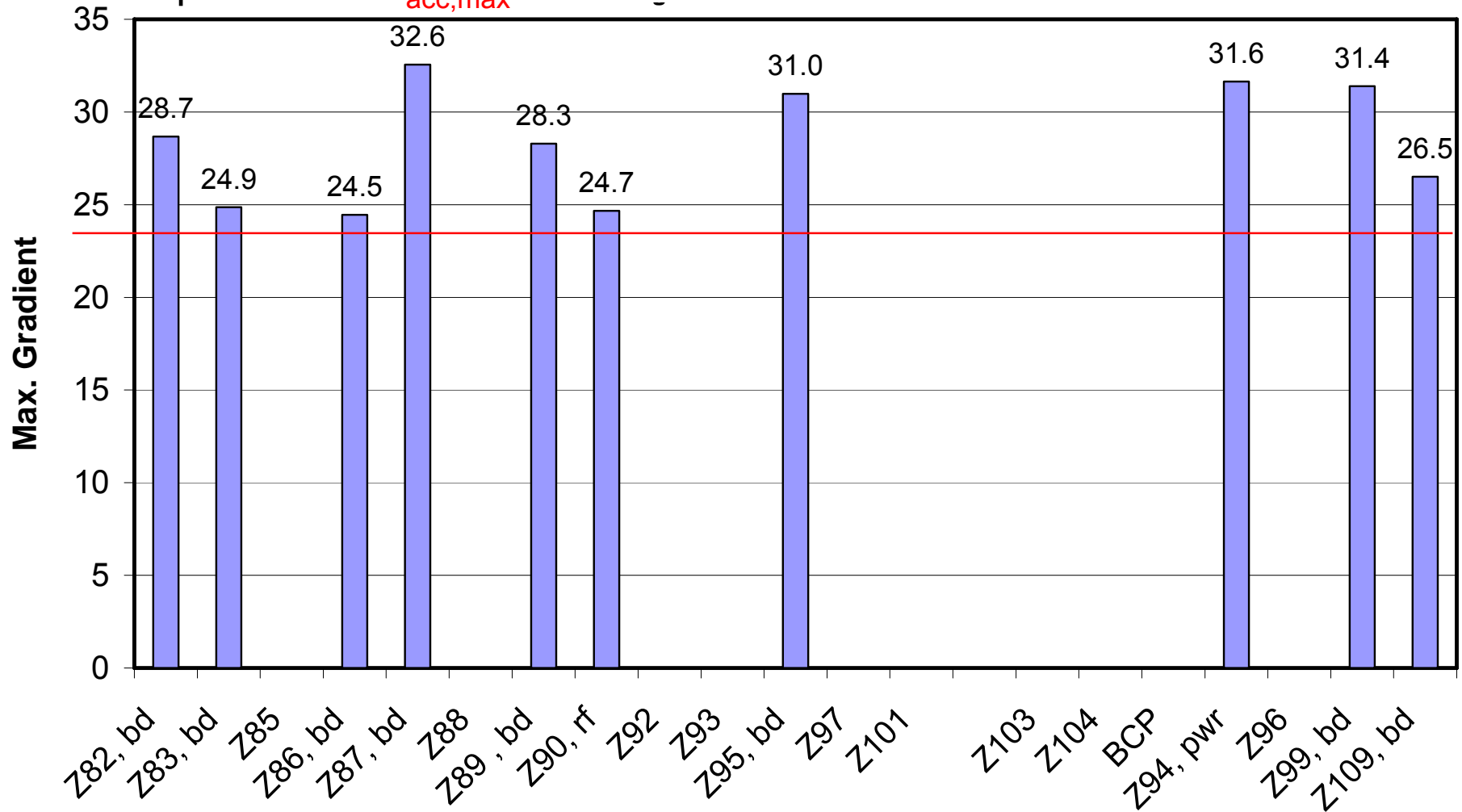
# $E_{acc,max}$ before and after 120C bake

- Comparison of  $E_{acc,max}$  before and after 120C bake:



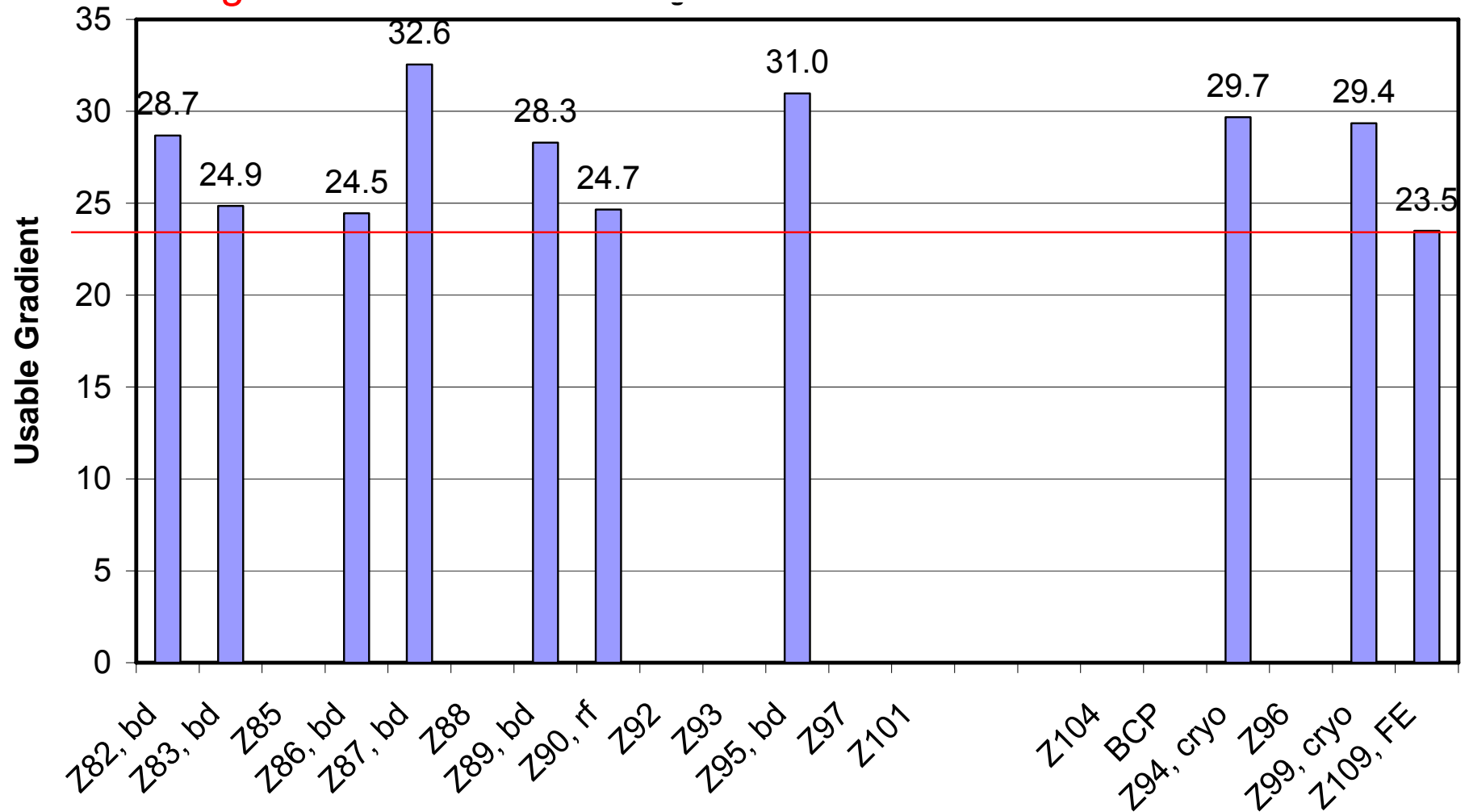
# $E_{\text{acc,max}}$ after 120C bake

- Comparison of  $E_{\text{acc,max}}$  after final EP and BCP-treatment after 120C bake:



# Usable gradient **after** 120C bake

- Usable gradient **after** final EP and BCP-treatment **after** 120C bake:



Cavity

# Quench locations of Z-cavities

- Table of quench locations :

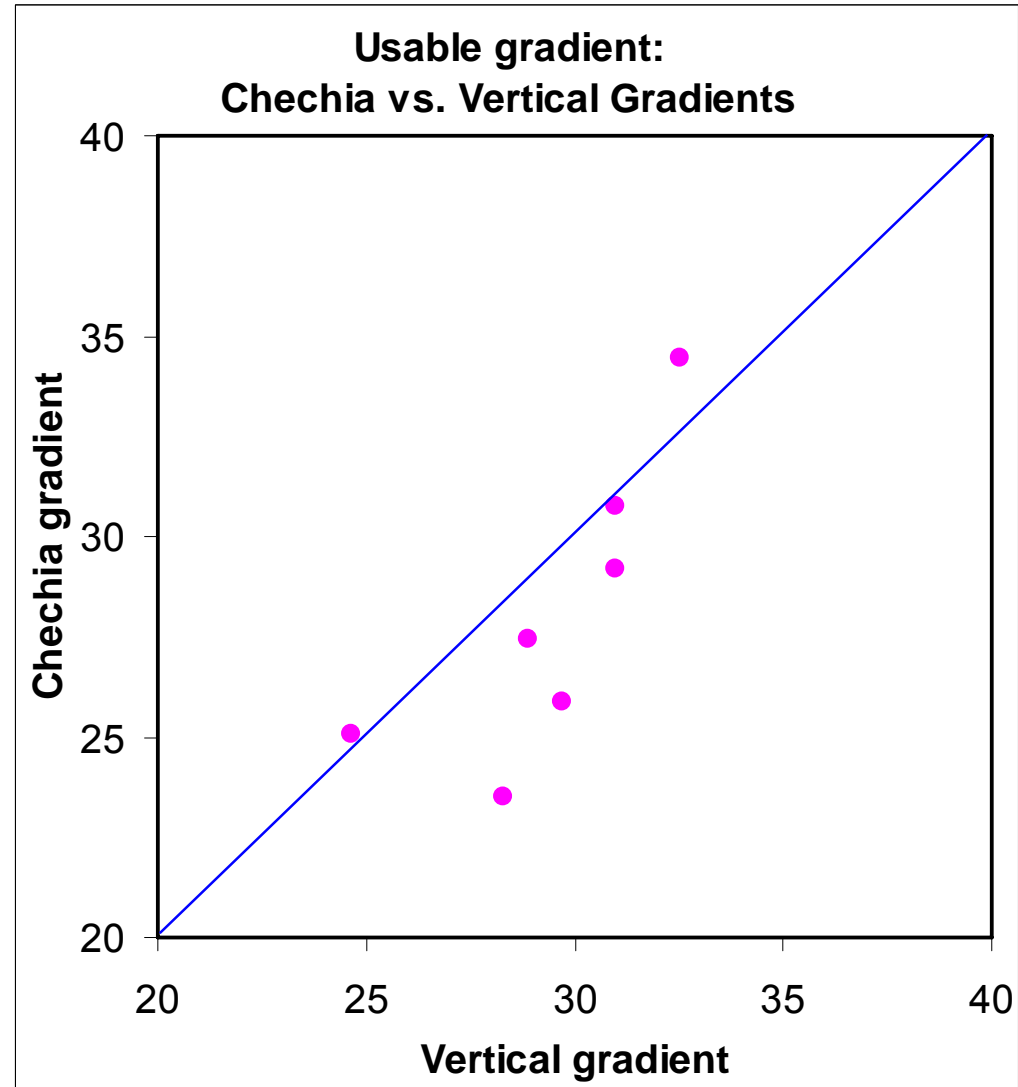
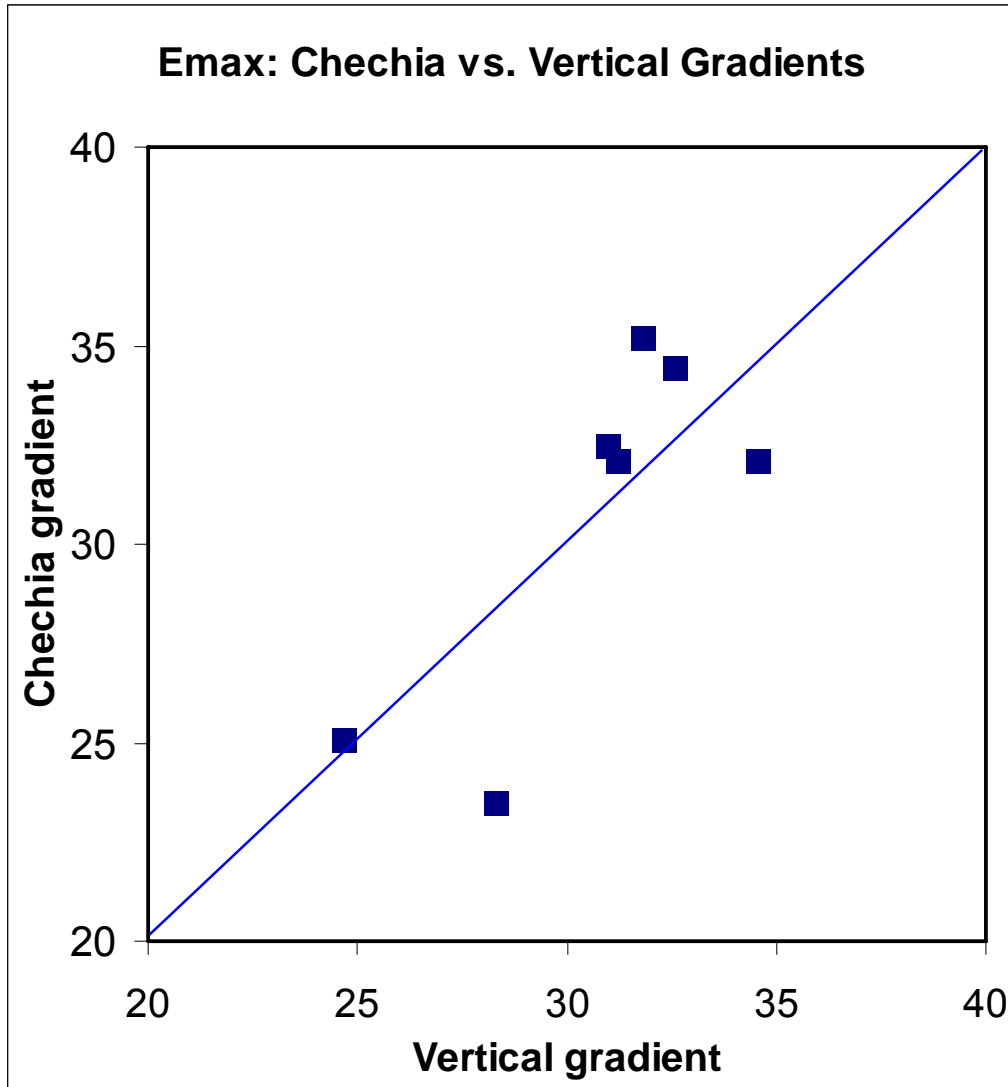
| Cavity      | Gradient | Quench location  | Preparation + remark |
|-------------|----------|--|----------------------|
| Z82, test 2 | 28 MV/m  | cell 9, <b>equator</b>   | EP + 127C; no FE     |
| Z83, test 2 | 25 MV/m  | cell 1 with two hot areas i) <b>equator</b> ; ii) upper cup                | EP + 127C; no FE     |
| Z85, test 2 | 33MV/m   | cell 3, <b>equator area; but highest dT 2 resistors off the equator ??</b> | EP + 124C; some FE   |
| Z87, test 1 | 29 MV/m  | cell 4, lower cup; far off equator   | EP; no FE            |
| Z89, test 2 | 28 MV/m  | 7/9pi-mode(!): cell 5, lower cup, hot area from equator to iris ??         | EP + 120C; some FE   |
| Z94, test 2 | 28 MV/m  | cell 3, upper cup, 3 resistors off the equator                             | BCP; few FE          |
|             |          |  |                      |
|             |          |  |                      |



# Chechia-Results

- Up to now 7 cavities Chechia-tested (incl. Z83 after 1350C-heat treatment)
- All cavities EP-processed with 2 EP-processed cavities **not** baked before Chechia => bad Qo
- Maximum gradient  $E_{\text{acc,max}}$   
=> **all cavities limited by quench between 23,5 MV/m to 35 MV/m**
- Usable gradient:
  - 3 cavities quench limited =>  $E_{\text{acc,max}} \approx$  **usable gradient**
  - 4 cavities exceed tolerable cryo losses (partially close to quench)

# Vertical vs. Chechia-Results



# Summary

- Broad scatter of both,  $E_{\text{acc,max}}$  and usable gradient in vertical and Chechia tests !!!
- 7 of 16 tested cavities are quench limited below 25 MV/m after EP-proc. !!  
=> 3 cavities (Z83 (pre-series with fabrication problems), Z86 + Z93) with “real” quench  
=> 4 cavities have field emission => FE induced quench??  
=> none (except of Z83) of these cavities had T-mapping investigation !!!
- 120C-bake often gives no improvement in  $E_{\text{acc}}$  due to quench limitation !!  
(but nevertheless some improvement in  $Q_0$  (cryo losses!!))
- Many cavities show significant field emission => preparation process not reproducible !!

# Conclusion

- Remaining cavities need full test program
  - with 120C bake for cavities with Q-slope ( $> 25 \text{ MV/m}$ )
  - T-Mapping for  $E_{\text{acc,max}} < 25 \text{ MV/m}$  (both EP- and BCP- final treatment)
- Data situation quite poor for XFEL cavity fabrication and preparation
- Final question:  
Is this performance of both, cavity fabrication and preparation process acceptable???  
(Remark: No cavity achieves the required ILC performance.)

# Addendum:

- Additional transparencies for explanation!

# T-Mapping

- Z 82 test 2 (after 800C, EP + 120C bake) => cell 9 equator
- Z83 test 2 (after 800C, EP + 120C) => cell 1 with 2 hot areas i) equator; ii) upper cup
- Z85 test 2 (after 800C, EP + 124C) => cell 3 equator area, but hottest dT 2 resistors off the equator??!!
- Z87 test 1 (after 800C, EP) => cell 4, lower cup, far off equator
- Z89 test 2 (after 800C, EP + 120C) => pi-mode gives no reasonable result; 7/9pi-mode shows quench in cell 5, lower cup, hot area from equator to iris
- Z94 test 2 (after 800C, **BCP**) => cell 3, upper cup, 3 resistors off the equator

# Why not first test for analysis before bake?

- EP-cavities with first test (11 of 16):  
Z82, Z83, Z86, Z87, Z88, Z89, Z90, Z97, Z102, Z103, Z104
- BCP-cavities with first test (3 of 4):  
Z96, Z99, Z109
- Why not first test?
  - Z85, test 4: test 1 before bake with strong FE  
test 2 after bake still strong FE  
test 3 with new EP, but rf problems
  - Z92, test 3: test 1 + 2 with 26MV/m without FE, but rf problems
  - Z93, test 2: test 1 with strong FE => alcohol rinse + HPR
  - Z94, test 2: only T-mapping added after test 1
  - Z95, test 2: test 1 with strong FE => HPR
  - Z101, test 2: only T-mapping added after test 1